Investigating the fate of gold nanoparticles taken up by trees through leaf and root pathways

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Industrial activities and human population growth have resulted in an unprecedented increase in the release of particulate matter (PM) into the environment. Incidental nanoparticles (NPs) as a byproduct of industrial processes and engineered NPs are being discharged into terrestrial and aquatic ecosystems. Several studies on the impact of PM and NPs on human health have been conducted this century, but their effects on plants are poorly understood. What happens to them in forest ecosystems and trees has yet to be explored. The use of dendrochemistry to monitor air pollution is essential to provide past levels of contamination. Several studies have shown the ability of trees to accumulate pollutants into their annual rings, but the effect of particles at nanoscale is still largely unknown and their presence in tree rings unexplored.

In July 2019, a greenhouse experiment was conducted in order a) to confirm the uptake and transport of NPs in trees, b) to determine the delivery efficiency of different NPs entry pathways (leaves and roots), and c) to investigate the influence of surface-charged NPs on their uptake and transport. The fate of gold nanoparticles (AuNPs) was investigated in two tree species, European beech (\textit{Fagus sylvatica} L.) and Scots pine (\textit{Pinus sylvestris} L.). In the experiment, 40nm surface-charged AuNPs (positive, negative, and neutral AuNPs, hereafter referred to as treatments) were supplied once, separately to leaves and to roots. Twenty days after the treatment, Au concentration (mg kg\textsuperscript{-1}) in leaves, stem and roots was determined by ICP-MS. In the leaf supply, Au concentrations were higher in leaves (98.3\% and 99.2\% on average, in beech and Scots pine respectively) and stems (1.4\% and 0.45\% on average) than in roots (0.3\% and 0.35\% on average). In the root supply, higher Au concentration was found in the roots (99.9 \% on average in both species) than in the stems (0.1\% on average in both species), whereas gold was not detected in the leaves. In the majority of cases, the measured Au was greater in beech than in Scots pine, probably due to their higher stomatal activity. AuNP concentrations among the treatments were significantly different (p value < 0.05), but distribution pattern in Scots pine were not discernible. In
conclusion, AuNPs can be taken up by roots and leaves and transported to different compartments of trees. Different entry pathways influence the NP delivery within the plant tissues through transport mechanisms that are still unclear. It seems that NPs are allowed to move faster from the leaves through the phloem to the xylem and are further distributed throughout the plant system, including to the roots. The influence of surface-charged nanoparticles on their uptake and transport is not completely clear, and further research is needed in order to understand their behavior in trees.

This study shows the potential of trees as proxies to monitor NPs in forest ecosystems. Using tree rings as spatiotemporal indicators of the impact of particles on the environment will help a quantitative risk assessment and management of atmospheric particulate matter and NPs concentrations in the environment.